Development and Use of “Fiberless” SMA in the United States

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Ingevity
Prompt: Agenda

- Acknowledgments
- Design of SMA
- Issues with Fibers
- Fiberless SMA
  - Concept
  - Design Techniques
  - Lab & Field Mix Performance Data
Acknowledgements

- Rutgers University (CAIT) – Presentation Prep
  - Tom Bennert
- NJ DOT
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- Associated Asphalt
  - Ron Corun
- Consultant
  - Frank Fee
- Ingevity - VA RT 29 Project cores/testing
  - Bryan Pecht, Dominic Barilla, Pete Truncale, Bill Criqui, Jason Bausano
Stone Matrix Asphalt (SMA)

- Gap graded aggregate blends with cubical shaped aggregate
- Mastic of polymer-modified asphalt binder, mineral filler and fibers
- When produced and placed correctly, known for outstanding performance
“SMA is a simple idea. Find a hard, durable, quality stone, fracture it into roughly cubical shape and of a size consistent with the proposed layer thickness, and then glue the stones together with a durable, moisture-resistant mortar of just the right quantity to give stone-to-stone contact among the coarse aggregate particles. For the asphalt technologist, the trick is getting the various parameters right.”
Due to high asphalt contents, a potential for “draindown” of binder exists:
- Defined as liquid binder running off aggregate surface
- Results in “fat spots” and segregated areas of high and low binder content
To help reduce the potential of draindown, polymer-modified asphalt (PMA) and fibers used with SMA

- PMA results in better adhesion to aggregate at higher temps than Neat binders (generally higher viscosity)
- Fibers increase stiffness of mastic by increasing surface area
Issues with Fibers

- Cost – fibers and rental equipment
- Fibers need to be separated or “fluffed” prior to addition or clumping can occur
- Metering required and should have “sight glass” to ensure fibers flowing
- Fibers must be included in ignition oven correction factor determination
  - Impossible to separate AC and Fiber changes during production from ignition oven testing
Example of Fiber Issue: “Fiber Ball” in New Jersey SMA

- Found in pavement surface during visual inspection after placement
- Possibly due to the “feeding system” at the asphalt plant
Fiberless SMA Concept & Design
Fiberless SMA Concept

- Fibers used to increase viscosity of mastic (binder + fines + fibers)
  - Increasing mastic viscosity will make it stick better to aggregate and resist draindown
- Using higher viscosity binder can help increase mastic viscosity
  - As temperature decreases, binder viscosity increases
- Reducing mixture temp will create compaction issues
  - Must couple mixture temp reduction with WMA additive
  - WMA technology that does not influence binder viscosity
Fiberless SMA “Mixture Design”

- General methodology
  - Use existing SMA design with fibers as starting point
    - (i.e. – asphalt content, aggregate blend)
  - Determine Draindown (AASHTO T305) & compacted air voids after reducing mixture temperature
    - Example: 325, 300, 280, 255°F
    - Design: Aggregates heated 10°F higher than compaction temp – compaction temperature used for specific binder grade
  - Compare draindown and compacted air voids
  - Examine mixing process to ensure coating is taking place (AASHTO T195, Degree of Particle Coating)
  - Make mix component adjustments if necessary
    - In general, have found for every 0.1% of cellulose fibers removed, asphalt plant will need to remove same amount of asphalt binder
Determine Optimal Temperature for Fiberless SMA in MD

- 12.5 mm NMAS SMA
- 6.5% Asphalt Content
  - PG76-22
- 0.3% Cellulose Fibers
- 0.04% Draindown at Design
  - Specification < 0.3%

### Washed Gradation

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<tr>
<th>Screen</th>
<th>% Pass</th>
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<tbody>
<tr>
<td>2&quot;</td>
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<tr>
<td>#200</td>
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Design Example #1: Compacted Air Voids vs Draindown
Final Result
- Optimal temp range for mixture between 255 and 265°F.
- In that range;
  - Air voids slightly above 4%
  - Draindown around 0.2 to 0.25% (specification is 0.3%)
  - All aggregates coated after mixing

Final production
- Maintained asphalt content and slight increase filler content
  - Increased filler to help close up air voids and reduce draindown
  - Contractor and agency extremely happy with final product
Design Example #2 – “Sometimes You Need a Few Trials”

- Determine Optimal Temperature Range for Fiberless SMA in VA
  - 12.5mm NMAS SMA
  - 6.7% Total Asphalt Content
    - PG76-22
  - 15% RAP
    - 0.4% Total Binder Weight Contribution
  - 0.3% Cellulose Fibers
  - 0.14% draindown

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<td>#200</td>
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</table>
Design Example #2 – Compacted Air Voids vs Draindown

6.7% Total Asphalt Content (6.3% Virgin Binder)
(Baseline Mix with Fibers: 325°F; 0.14% Draindown; 4.4% Compacted Air Voids)

Draindown (%)
Compacted Air Voids (%)

High Draindown created issues with compaction
1\textsuperscript{st} Trial Results

- Testing at lower temps showed that air voids were slightly low and draindown was still above specification
  - Coating easily met at all temperatures
- For this particular mix, the elimination of fibers is creating an slightly over-asphalted mix
- For Trial \#2, asphalt content was reduced 0.3\% (same \% as original fibers) and testing was again conducted
Design Example #2 – 2nd Trial Results

6.4% Total Asphalt Content (6.0% Virgin Binder Content)
(Baseline Mix with Fibers: 325°F; 0.10% Draindown; 4.7% Compacted Air Voids)

Compacted Air Voids (%) vs. Draindown (%) vs. Mix Temperature (°F)

- Compacted Air Voids (%)
- Draindown (%)

Mix Temperature (°F):
- 250
- 260
- 270
- 280
- 290
- 300
- 310
- 320
- 330

Compacted Air Voids (%):
- 0.19
- 0.76
- 1.1
- 1.54
- 4.90
- 5.09
- 7.32
- 6.36

Draindown (%):
- 0
- 0.5
- 1
- 1.5
- 2
- 2.5
- 3
- 3.5
- 4
For the Design Example #2 SMA, eliminating fibers created an over-asphalted condition

- Fibers creating surface area – taking up additional asphalt

2nd trial showed a reduction of 0.3% asphalt was required to maintain draindown

Supplier also slightly increased dust to help tighten up air voids
Fiberless SMA Field and Laboratory Performance
First project to look at fiberless SMA with WMA (2009)

Location: Rt 1, SB in New Jersey (MP 6.5 to 7.8)
- Rt 1 NB constructed with conventional SMA
- Trap Rock aggregate
- 12.5mm SMA
- 6.4% AC content-Same w/o fibers
- PG76-22
- 0.3% cellulose fibers

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</tr>
<tr>
<td>#200</td>
<td>0.075 8.8</td>
</tr>
</tbody>
</table>
### Project #1 – NJ, Rt. 1 SB

- Air voids ranged between 3.8% to 4.4%
- Aggregate coating no issue

<table>
<thead>
<tr>
<th>Mixture ID</th>
<th>Temperature (F)</th>
<th>Percent Draindown</th>
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<tbody>
<tr>
<td></td>
<td>Mixing</td>
<td>Testing</td>
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<tr>
<td>Normal SMA</td>
<td>325</td>
<td>325</td>
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<tr>
<td>WMA SMA #1 (No Fibers)</td>
<td>325</td>
<td>325</td>
</tr>
<tr>
<td>WMA SMA #2 (No Fibers)</td>
<td>290</td>
<td>290</td>
</tr>
<tr>
<td>WMA SMA #3 (No Fibers)</td>
<td>255</td>
<td>255</td>
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</tbody>
</table>

Supplier did own assessment of compacted air voids
NJ Rt 1 - Dynamic Modulus for Mixture Stiffness
NJ Rt 1 – Wet Hamburg Wheel Tracking for Stripping & Rutting Potential

Cycles to 12.5mm Rutting = > 20,000 cycles
### SMA - WMA with No Fibers

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Temp (F)</th>
<th>Displacement (inches)</th>
<th>Fatigue Life (cycles)</th>
</tr>
</thead>
<tbody>
<tr>
<td># 1</td>
<td>77 F</td>
<td>0.025&quot;</td>
<td>10,472</td>
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<tr>
<td># 2</td>
<td>77 F</td>
<td>0.025&quot;</td>
<td>27,855</td>
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<td># 3</td>
<td>77 F</td>
<td>0.025&quot;</td>
<td>16,255</td>
</tr>
</tbody>
</table>

Average (Trimmed Mean) = 18,194

### SMA - Normal Production

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Temp (F)</th>
<th>Displacement (inches)</th>
<th>Fatigue Life (cycles)</th>
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<tbody>
<tr>
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<td>77 F</td>
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<tr>
<td># 2</td>
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<td># 3</td>
<td>77 F</td>
<td>0.025&quot;</td>
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Average (Trimmed Mean) = 2,003
Project #1 – New Jersey
Project #1 – New Jersey
Field Core Density

- Conventional SMA Density = 5.13% air voids
  - Produced over 315F
- WMA SMA Density = 5.12% air voids
  - Produced under 280F
- Both mixtures were identical with regard to density
Fiberless using WMA SMA Project #1 – New Jersey Rt 1 Southbound

- For initial pilot, reduction in production temp successfully reduced draindown when fibers eliminated
  - Produced @ 275 to 285°F
  - 1st Roller Pass @ 270 to 280°F
- Field densities of with and without fibers statistically equal
- Mixture performance looked good
  - Lower production temps not aging binder as normal
    - Stiffness slightly lower
    - Large increase in fatigue resistance (higher effective AC?)

One Complaint!
Project #2 – New Jersey

- Fiberless SMA (2012) – NB Rt 1
  - Approximately MP 28.5 to 32.1
- Supplier conducted draindown and compaction on own
  - AC% = 6.1%; no fibers; PG76-22 asphalt binder, 0.6% WMA
- Produced @ 275 to 285F
- 1st Roller Pass @ 270 to 280F
  - Average of 5% air voids in the field
- Rutgers received loose mix to evaluate/compare general performance properties
Project #2 – NJ – Mixture Stiffness
Project #2 – NJ - Rutting Resistance

64°C Test Temp.; 100psi Hose Pressure; 100 lb Load Load

APA Rutting @ 8,000 Cycles

SMA = 2.43 mm (Std Dev = 0.26 mm)
SMA = 3.01 mm (Std Dev = 0.10 mm)
Project #2 – NJ – Fatigue Resistance

Overlay Tester Fatigue Life (cycles)

- WMA SMA: 2247 cycles
- SMA: 244 cycles
- Mixture performance between SMA and WMA - SMA similar
  - Decreased production temps results in slightly less stiff WMA fiberless mixture
  - Eliminating fibers and reducing temps results in superior fatigue resistance
- Properly designed SMA with PMA and stone-on-stone contact (assuming quality stone) should not rut
Supplier and Contractor Comments/Opinions
Produced 1\textsuperscript{st} Fiberless SMA and 4 to 5 projects since

- Mix Design
  - Able to reduce asphalt binder content by 0.4\% while still improving fatigue properties. Reduction in binder more than paid for addition of WMA additive
  - Fiberless eliminated the need for purchasing, delivering, stockpiling and protecting fibers – no rental costs
  - Can take an order of SMA one day and start producing the next

- No plant modifications necessary

- Field/Compaction
  - Workability (hand work) and compaction excellent, even as low as 265\textdegree{}F in the northeast
  - Ship 1\textsuperscript{st} load or two at normal temp to heat up MTV and paver, then go back to warm mix temps
  - No issues with material sticking to truck bodies
Supplier Opinions – Tilcon Mt. Hope, NJ

- Produced two Fiberless SMA projects
  - Mix Design
    - Reduced asphalt content by 0.4% - lab testing at Rutgers showed good fatigue cracking performance
    - Saved costs on both no fibers and reduced asphalt content
  - No plant modifications necessary during production
    - Production 280 to 290°F with PG76-22 compared to > 325°F
  - Field/Compaction
    - Better workability than conventional SMA
    - Truck bodies clean
    - Compaction still as low as 170°F – densities better than 94% Gmm
VA Route 29 Fiberless SMA Trial
Paved in 2013
Field Core Evaluation
VDOT and Superior Paving constructed a fiberless SMA as a trial
1,100 tons of fiberless SMA in the SB (left) lane
Volumetric properties were in specification; no issues with density or drain down issues
Superior lowered plant temps by ~50°F by adding WMA when removing fibers
Plant production 285°F - 290°F
Roadway production 275°F - 280°F
When using WMA and no fibers:
  - lower cost per mix ton
  - increased plant production
  - reduced mixing time
Mix Designs

FIBERLESS
- 15% RAP
- 9.6% P200
- 6.0% AC
- PG 76-22
- 0.6% WMA

CONVENTIONAL
- 12% RAP
- 9.5% P200
- 6.3% AC
- PG 76-22
- 0.3% Cellulose Fibers
- 0.3% LAS
Road Core E&R Binder Grade, %AC

VA Rt 29 Cores Binder E&R, AC%

- Fiberless
  - PG 76-22: 5.43% AC
  - PG 76-22: -23.2

- w/ Fibers
  - PG 76-16: 6.07% AC
  - PG 76-16: -21.4

Legend:
- PG T High failure, C
- PG T low failure, PAV20, C
Overlay Test TEX-248-F

Avg Cycles to Failure

Avg Cycles to Failure Fiberless

Avg Cycles to Failure with Fibers
Overlay Test TEX-248-F (all data)
Overlay Test TEX-248-F (All Data)

![Graph showing critical fracture energy versus crack progression rate with failure limit, upper limit, and lower limit]

- **Tough-Crack Resistant**
- **Tough-Crack Susceptible**
- **Soft-Crack Resistant**
- **Soft-Crack Susceptible**

- **Critical Fracture Energy (in²/lb/in²)**
- **Crack Progression Rate**

Legend:
- Red line: Failure Limit
- Dashed red line: Upper Limit
- Green line: Lower Limit
Overlay Test TEX-248-F (Fiber-less)

The diagram illustrates the relationship between Crack Progression Rate and Critical Fracture Energy [in*lbs/in^2]. The graph is divided into two categories: Tough-Crack Resistant and Soft-Crack Resistant, and Tough-Crack Susceptible and Soft-Crack Susceptible. Points are plotted for different samples labeled NF-9, NF-11, NF-12, and NF-15, indicating their respective positions in the graph.
Overlay Test TEX-248-F (with Fibers)

The graph illustrates the relationship between Crack Progression Rate and Critical Fracture Energy (in * lbs/in²) for different samples labeled F-7, F-10, F-12, and F-13. The categories 'Tough-Crack Resistant' and 'Soft-Crack Resistant' are indicated, as well as 'Tough-Crack Susceptible' and 'Soft-Crack Susceptible'.
Questions?